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(19) (CA) APPLICATION FOR CANADIAN PATENT (12)

(54) Soft Toric Lens for Correction of Astigmatism

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(57) 12 Claims

5,087,9/64

Notice: This application is as filed and may therefore contain an incomplete specification.

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ABSTRACT OF THE DISCLOSURE

A toric contact lens for correction of astigmatism comprises a concave posterior surface to be applied to a wearer's eye, and a convex anterior surface symmetrical about an horizontal plane of symmetry. The anterior surface comprises a central optical zone, and a pair of upper and lower peripheral prismatic zones situated outside the central optical zone and symmetrical about the horizontal plane of symmetry. Each prismatic zone defines an apex along the peripheral edge of the lens, and the lens has, in the region of each prismatic zone, a thickness that gradually increases from this apex toward the central optical zone whereby sliding movement of the eyelids on the prismatic zones pushes these zones to produce a stabilizing effect that maintains the contact lens in a desired, predetermined orientation. The anterior surface further comprises an intermediate aspheric zone surrounding the central optical zone and forming a smooth transition surface between this optical zone and the two peripheral prismatic zones.

5 SOFT TORIC LENS FOR CORRECTION OF ASTIGMATISM10 BACKGROUND OF THE INVENTION1. Field of the invention:

15 The present invention relates to a toric contact lens for astigmatic correction.

2. Brief description of the prior art:

20 As well known to those of ordinary skill in the art, the angular orientation of toric contact lenses must be maintained constant to prevent deviation of the astigmatic correction from the desired axis.

25 To prevent rotation thereof, prior art toric contact lenses comprise an anterior surface formed with a prismatic central optical zone adapted to increase the thickness of the lower portion of the lens. The additional weight in the lower portion of
30 the lens then produces an effect of ballast that maintains the lens in the required angular orientation. A prismatic central optical zone presents the drawback of producing prismatic aberrations that reduce the optical quality of the
35 lens and therefore the visual acuity of the patient. Moreover, the prismatic central optical zone increases the thickness of the lens to thereby reduce both the

comfort of the patient's eye and the transmission of oxygen to the eye's cornea. As well known to those skilled in the art, tolerance of the eyes to contact lenses reduces with the thickness of the lenses.

5

Another prior art method to prevent rotation of a toric contact lens is described in United States patent N° 5,020,898 (Townesley). This method consists of forming the anterior surface of the lens with peripheral upper and lower non symmetrical prismatic zones creating an effect of ballast. More specifically, this prismatic geometry increases the thickness of the lower portion of the lens and the additional weight of this lower portion maintains the lens in the desired angular position. The drawbacks of this method are the production of prismatic aberrations in the lens's optical system and the increase of thickness in the central region of the lens.

20

A further prior art method to prevent rotation of the toric contact lens consists of forming the lens with two diametrically opposed thinned zones. Upon movement of the eyelids on these thinned zones, the eyelids tend to push the thicker central portion of the lens to ensure stability thereof. A major disadvantage of this method is that the lens should be made thicker in the central region to enable formation of efficient thinned zones.

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OBJECT OF THE INVENTION

5 An object of the present invention is
therefore to provide a toric contact lens for
astigmatic patients that eliminate the above mentioned
drawbacks of the prior art.

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SUMMARY OF THE INVENTION

15 More specifically, in accordance with the
present invention, there is provided a toric contact
lens for astigmatic correction, comprising a
peripheral edge, a concave posterior surface to be
applied to a patient's eye and formed with a
substantially central toric zone to optically correct
astigmatism of the patient's eye, and a convex
20 anterior surface symmetrical about an horizontal plane
of symmetry.

 The convex anterior surface of the toric
contact lens of the invention comprises:

25 a substantially central optical zone; and
a pair of upper and lower peripheral
prismatic zones situated outside the central optical
zone and symmetrical about the horizontal plane of
symmetry, wherein each prismatic zone defines an apex
30 along the peripheral edge of the lens, and wherein the
lens has, in the region of each prismatic zone, a
thickness that gradually increases from this apex
toward the central optical zone;

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whereby sliding movement of the eyelids of the patient on the upper and lower prismatic zones pushes these prismatic zones to produce a stabilizing effect that maintains the contact lens on the patient's eye in a desired, predetermined angular orientation.

In accordance with preferred embodiments of the present invention, the central optical zone is spherical, the upper and lower prismatic zones have the general configuration of a crescent moon, and the anterior surface further comprises an intermediate aspheric zone surrounding the central optical zone and forming a smooth transition surface between this optical zone and the upper and lower peripheral prismatic zones.

Advantageously, the anterior surface is symmetrical about a vertical plane of symmetry, the upper and lower prismatic zones are symmetrical about this vertical plane of symmetry, and the anterior surface further comprises peripheral spherical zones symmetrical about the vertical plane of symmetry, the lens being thinned in the region of these peripheral spherical zones.

The combination of a spherical central optical zone, an intermediate aspheric zone, upper and lower peripheral prismatic zones and peripheral thinned zones enables production of a toric contact lens that is thin and free from prismatic aberrations.

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In accordance with a further preferred embodiment of the invention, the posterior surface comprises the above mentioned central toric zone, an intermediate spherical zone, and a peripheral zone defining a surface tangential to the surface of the intermediate spherical zone, the intermediate spherical zone being located between the toric zone and the peripheral zone of the posterior surface.

The objects, advantages and other features of the present invention will become more apparent upon reading of the following non restrictive description of a preferred embodiment thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

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In the appended drawings:

Figure 1 is a front elevational view of a soft toric contact lens in accordance with the present invention for astigmatic correction, showing an anterior surface of this lens;

Figure 2 is a side elevational, cross sectional view of the contact lens according to the invention, taken along line A-A of Figure 1 and showing details of a central optical zone of the anterior surface of this lens;

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Figure 3 is a cross sectional, bottom plan view of the contact lens according to the invention, taken along line B-B of Figure 1 and showing details of the central optical zone of the anterior surface of this lens;

Figure 4 is a side elevational, cross sectional view of the contact lens according to the invention, taken along line A-A of Figure 1 and showing details of upper and lower peripheral prismatic zones of the anterior surface of this lens;

Figure 5 is a cross sectional, bottom plan view of the contact lens according to the invention, taken along line B-B of Figure 1 and showing details of an intermediate aspheric zone of the anterior surface of this lens;

Figure 6 is a cross sectional, bottom plan view of the contact lens according to the invention, taken along line B-B of Figure 1 and showing details of peripheral thinned zones of the anterior surface of this lens;

Figure 7 is a rear elevational view of the soft toric contact lens in accordance with the present invention for the correction of astigmatism, showing a posterior surface of this lens;

Figure 8 is a side elevational, cross sectional view of the contact lens according to the invention, taken along line C-C of Figure 7 and showing details of a central toric zone and an

Figure 9 is a cross sectional, bottom plan
5 view of the contact lens according to the invention,
taken along line D-D of Figure 7 and showing details
of the central toric zone and intermediate spherical
zone of the posterior surface of this lens;

15

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the specification and the appended claims, the term "vertical" and "horizontal" are used with reference to the lens as it would be if ideally seated on the cornea of the eye without any shift in orientation resulting by movement caused by the eyelid. Regarding the term "rotation", it refers to rotation of the lens when seated on the cornea of the eye.

As illustrated in Figure 1, the preferred embodiment of the soft toric contact lens 1 in accordance with the present invention comprises an anterior surface 2 formed with a central optical zone 3, an intermediate aspheric zone 4, two upper and lower peripheral prismatic zones 5 and 6, two peripheral thinned zones 7 and 8, and two reference points 9 and 10. The anterior surface 2 of the lens 1 is symmetrical about an horizontal plane of symmetry containing horizontal axis 11, and about a vertical plane of symmetry containing vertical axis 12.

In Figures 1 and 7 of the appended drawings, while curves appear to delineate distinct zones of the lens they are shown for clarity of description of the invention only. It will be appreciated by those of ordinary skill in the art that there are no sharp distinction between these different zones of the lens, but they are smoothly blended into one another.

Central optical zone 3:

The central optical zone 3 is the only zone of the anterior surface that optically corrects defects of the patient's eye.

The central optical zone 3 is spherical and, therefore, has a constant radius R (Figure 2). The axis of rotation of the central optical zone 3 corresponds to the axis of rotation 21 of the entire lens 1, whereby this central optical zone 3 is not a

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prismatic surface and accordingly does not present the drawback of producing prismatic aberrations.

Referring to Figures 2 and 3, the chord
 5 C of the central optical zone 3 varies between 7,63 and 8,80 mm, according to the relation $C = 8,8/F$, in which $F = DT/15$, DT being the diameter of the lens 1. The central thickness E (Figure 2) may have values situated between 0,09 and 0,49 mm, depending on the
 10 dioptric power of the lens 1.

Peripheral prismatic zones 5 and 6:

15 As indicated in the foregoing description, rotation of a toric lens 1 must be prevented to avoid deviation of the astigmatic correction from the desired axis. In the lens 1 according to the invention, upper and lower peripheral prismatic zones
 20 5 and 6 fulfill this function.

As illustrated in Figure 1, the prismatic zones 5 and 6 have the general configuration of a crescent moon and are situated outside the central
 25 optical zone 3. They are also symmetrical about the horizontal plane of symmetry containing horizontal axis 11.

The upper prismatic zone 5 is generated,
 30 as illustrated in Figure 4, by shifting its axis of rotation 13 vertically and downwardly from the axis of rotation 21 of the toric lens 1 by a distance D10. The radius of curvature R10 of the zone 5 is constant.

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In the same manner, the axis of rotation 14 of the lower prismatic zone 6 is vertically and upwardly shifted from the lens' axis of rotation 21 by a distance D20. The radius of curvature R20 of the zone 6 is again constant.

The distances D10 and D20 are identical but opposite, and can vary between 0,10 and 0,60 mm. The radius of curvature R10 and R20 are also identical and vary in function of the other parameters of the lens 1.

As illustrated in Figure 4, the prismatic zones 5 and 6 define an apex situated along the peripheral edge 20 (Figure 11) of the lens in the region of the vertical plane of symmetry containing axis 12. Also, the lens has, in the region of each prismatic zone 5, 6, a thickness that gradually increases from this apex toward the central optical zone 3.

From the foregoing description, one of ordinary skill in the art will appreciate that the zones 5 and 6 are prismatic and are opposed by their bases to simulate the conventional thinned zones discussed in the above brief description of the prior art. Indeed, due to their prismatic and crescent moon configuration, sliding movement of the wearer's upper and lower eyelids on the upper and lower prismatic zones 5 and 6, respectively, will tend to push these prismatic zones to thereby produce a stabilizing effect that maintains the contact lens 1 on the patient's eye in the desired, predetermined angular

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orientation corresponding to the orientation of Figure 1.

5 The advantage of that solution is that the two prismatic zones 5 and 6 are situated in the periphery of the lens 1 and do not affect the central optical zone 3 of the lens 1. This enables production of a lens having a thinner central optical zone 3 free from prismatic aberrations.

10 It should also be pointed out here that the transmission of oxygen through a contact lens reduces with the thickness of that lens. Accordingly, a thinner lens 1 transmits more oxygen to the cornea
15 and therefore affects its metabolism to a lesser extent.

20 Those of ordinary skill in the art know that the prismatic aberrations reduce the optical quality and therefore the visual acuity of the patient. Accordingly, a lens formed with no prism in the central optical zone provides the user with a higher visual acuity.

25 Intermediate aspheric zone 4:

30 The anterior surface 2 of the lens 1 is therefore formed of three main zones: the central optical zone 1 and the upper and lower peripheral prismatic zones 5 and 6. A fourth zone, namely the intermediate aspheric zone 4 interconnects the central optical zone 3 and the two peripheral prismatic zones 5 and 6.

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The use of an aspheric intermediate zone 4 flattens the anterior surface 2 of the lens 1; the aspheric zone 4 enables elimination of the prior art abrupt junctions between the central optical zone 3 and the intermediate zone 4 which reduces the comfort of the patient's eye and the stability of the lens upon blinking movement of the upper eyelid. In the same manner, the aspheric zone 4 eliminates any abrupt junction between the intermediate zone 4 and the peripheral prismatic zones 5 and 6. Therefore, the aspheric zone 4 forms a smooth transition between the optical zone 4 and the upper and lower peripheral prismatic zones 5 and 6.

More specifically, the surface of the intermediate aspheric zone 4 is defined by a progressive elongation of the radius of curvature ($R_1 < R_2 < R_3 < R_n$) as shown in Figure 5. The transition is progressive and invisible whereby the anterior surface 2 is smoother and interference of the lens 1 with movement of the upper and lower eyelids is, if not eliminated, substantially reduced.

Peripheral thinned zones 7 and 8:

The two peripheral and spherical thinned zones 7 and 8 (Figures 1 and 6), which are symmetrical about the vertical plane of symmetry containing vertical axis 12, improve the comfort of the patient's eye. Indeed, by making the lens 1 thinner in the region of the zones 7 and 8, that is at the junction of the prism, lifting of the upper eyelid upon blinking movement thereof is reduced whereby

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perturbation of the upper eyelid is also substantially reduced. Too important a mass at the periphery of the lens 1 would lift the upper eyelid upon movement thereof and, therefore, would affect natural
5 lubrication of the eye's sclera adjacent a peripheral thick portion of the contact lens.

Reference points 9 and 10:

10

Referring back to Figure 1, the anterior surface 2 of the lens 1 is provided with a pair of diametrically opposed reference points 9 and 10 situated along the horizontal axis 11. These
15 reference points enable the practitioner to evaluate the direction and the amplitude of the rotation (shift of the axes 11 and 12) of the lens 1 on the eye of the patient. This will enable fabrication of a contact lens whose parameters are chosen to eliminate this
20 rotation.

The lens 1 in accordance with the present invention further comprises a posterior surface 15
25 (Figure 7) formed with a central toric zone 16, an intermediate spherical zone 17, a peripheral tangential zone 18, and a lens edge 20.

Central toric zone 16:

30

The central zone 16 of the posterior surface 15 is toric. More specifically, the central toric zone 16 comprises a first radius of curvature

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R30 (Figure 8) corresponding to the minor meridian of the toric zone 16. It also comprises a second radius of curvature R40 (Figure 9) corresponding to the major meridian of the toric zone 16, this major meridian being orthogonal to the minor meridian and intersecting the minor meridian at the geometrical center of the lens. As can be seen, $R30 < R40$. These two radii of curvature are determined by the optical prescription.

10

Chord C30 (Figure 8) of the central toric zone 16 corresponds to the radius of curvature R30, while chord C40 (Figure 9) corresponds to the radius of curvature R40. As can be seen in Figures 8 and 9, $C30 < C40$. The longer chord C40 has a length varying between 10,40 and 12,00 mm proportionally to the total diameter DT of the lens 1, in relation to the above mentioned factor F. The shorter chord C30 varies in relation to the radius of curvature R30.

20

In the embodiment illustrated in Figure 7, the major meridian of the toric zone 16 lies on the horizontal axis 11 while the minor meridian of the toric zone 16 lies on the vertical axis 12. However, it should be kept in mind that, alternatively, the major and minor meridians may be at an oblique angle to the axes 11 and 12 depending on the prescription of the patient.

30

The central zone 16 is therefore a toric surface that is responsible for the astigmatic correction. It also enables a perfect alignment of

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the lens 1 with the surface of the cornea which is also toric.

Intermediate spherical zone 17:

5

As illustrated in Figure 7, the intermediate spherical zone 17 surrounds the central toric zone 16 and interconnects this central toric zone 16 and the peripheral tangential zone 18. This zone 17 is spherical, generated by a single radius of curvature R50 (Figures 8, 9 and 10). The chord C50 of the spherical zone 17 which varies between 11,27 and 13,00, proportionally to the total diameter DT of the lens 1, is given by the relation

15

$$C50 = 13 \times F$$

where $F = DT/15$, as indicated in the foregoing description.

20

The radius of curvature R30 and R40 of the central toric zone 16 are shorter than the radius of curvature R50 of the intermediate spherical zone 17 and define a toric vault having a deepness PVT varying between 0,13 and 0,15 mm proportionally to the total diameter DT of the lens 1, in accordance with the following relationship:

25

$$PVT = 0,15 \times F$$

30

in which $F = DT/15$.

Peripheral tangential zone 18:

Referring to Figure 11, the peripheral tangential zone 18 is a conical surface defining an open angle α with the prolongation 19 of the intermediate spherical zone 17. As the peripheral zone 18 is tangential to the intermediate spherical zone 17, no junction exists between these two zones of the posterior surface 15. The width L (Figure 7) of the tangential zone 18 varies between 0,87 and 1,00 mm proportionally to the total diameter DT of the lens 1, in relation to the factor F.

The function of the peripheral tangential zone 18, defining an open angle α , is to distribute the pressure of the lens 1 on the sclero-corneal limbus, and to prevent (a) pressure indentation of the edge 20 (Figure 11) of the lens 1 into the sclera and (b) perturbation of the circulation in the small blood vessels of the sclera.

Lens edge 20:

As illustrated in Figure 11, the peripheral edge 20 of the lens 1 is formed with a rounded profile to reduce to the minimum the interaction between the edges of the upper and lower eyelids with the edge 20 of the lens 1. This improves both comfort of the patient's eye and stability of the contact lens.

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Although other materials can be contemplated, the toric contact lens 1 in accordance with the present invention is advantageously made of an hydrophillic material with a high content of water
 5 (at least 55%) in order to ensure comfort of the patient's eye and a permeability to oxygen sufficient to respect the corneal metabolism.

The available parameter ranges for the
 10 lens 1 in accordance with the present invention are the following:

- Base curves	7,50	to	9,50 mm
- diameters	13,00	to	15,00 mm
15 - power sphere	-20,00	to	+20,00 diopters
cylinders	-0,75	to	-10,00 diopters
axes	0	to	180°

The above wide ranges of available
 20 parameters make the lens 1 according to the invention a high performance contact toric lens.

In the foregoing description, any numerical value or range is given for the purpose of
 25 exemplification only and should not be interpreted to limit the scope of the invention.

Although the present invention has been described hereinabove by way of a preferred embodiment
 30 thereof, this embodiment can be modified at will, within the scope of the appended claims, without departing from the spirit and nature of the subject invention.

WHAT IS CLAIMED IS:

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1. A toric contact lens for astigmatic correction, comprising a peripheral edge, a concave posterior surface to be applied to a patient's eye and formed with a substantially central toric zone to optically correct astigmatism of the patient's eye, and a convex anterior surface symmetrical about an horizontal plane of symmetry and comprising:

a substantially central optical zone; and

a pair of upper and lower peripheral prismatic zones situated outside the central optical zone and symmetrical about said horizontal plane of symmetry, wherein each prismatic zone defines an apex along the peripheral edge of the lens, and wherein said lens has, in the region of each prismatic zone, a thickness that gradually increases from said apex toward the central optical zone;

whereby sliding movement of the eyelids of the patient on the upper and lower prismatic zones pushes said prismatic zones to produce a stabilizing effect that maintains the contact lens on the patient's eye in a desired, predetermined angular orientation.

2. A contact lens as recited in claim 1, wherein said substantially central optical zone is spherical.

3. A contact lens as recited in claim 1, wherein said upper and lower prismatic zones have the general configuration of a crescent moon.

4. A contact lens as recited in claim 1, wherein said anterior surface is symmetrical about a

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vertical plane of symmetry, and wherein said upper and lower prismatic zones are symmetrical about said vertical plane of symmetry.

5. A contact lens as recited in claim 1, wherein said anterior surface further comprises an intermediate aspheric zone surrounding said optical zone and forming a smooth transition surface between said optical zone and said upper and lower peripheral prismatic zones.

6. A contact lens as recited in claim 1, wherein said anterior surface is symmetrical about a vertical plane of symmetry, and wherein said anterior surface further comprises peripheral spherical zones symmetrical about said vertical plane of symmetry, said lens being thinned in the region of said peripheral spherical zones.

7. A contact lens as recited in claim 1, in which said posterior surface comprises said substantially central toric zone, an intermediate spherical zone, and a peripheral zone defining a surface tangential to the surface of the intermediate spherical zone, said intermediate spherical zone being located between said toric zone and said peripheral zone of the posterior surface.

8. A toric contact lens for astigmatic correction, formed with a peripheral edge, a concave posterior surface to be applied to a patient's eye and formed with a substantially central toric zone to optically correct astigmatism of the patient's eye, and a convex anterior surface symmetrical about an horizontal plane of symmetry and comprising:

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a substantially central optical spherical zone;

a pair of upper and lower peripheral prismatic zones situated outside the central optical zone and symmetrical about said horizontal plane of symmetry, wherein each prismatic zone defines an apex along the peripheral edge of the lens, and wherein said lens has, in the region of each prismatic zone, a thickness that gradually increases from said apex toward the central optical zone, whereby sliding movement of the eyelids of the patient on the upper and lower prismatic zones pushes said prismatic zones to produce a stabilizing effect that maintains the contact lens on the patient's eye in a desired, predetermined angular orientation; and

an intermediate aspheric zone surrounding said optical zone and forming a smooth transition surface between said optical zone and said upper and lower peripheral prismatic zones.

9. A contact lens as recited in claim 8, wherein said upper and lower prismatic zones have the general configuration of a crescent moon.

10. A contact lens as recited in claim 8, wherein said anterior surface is symmetrical about a vertical plane of symmetry, and wherein said upper and lower prismatic zones are symmetrical about said vertical plane of symmetry.

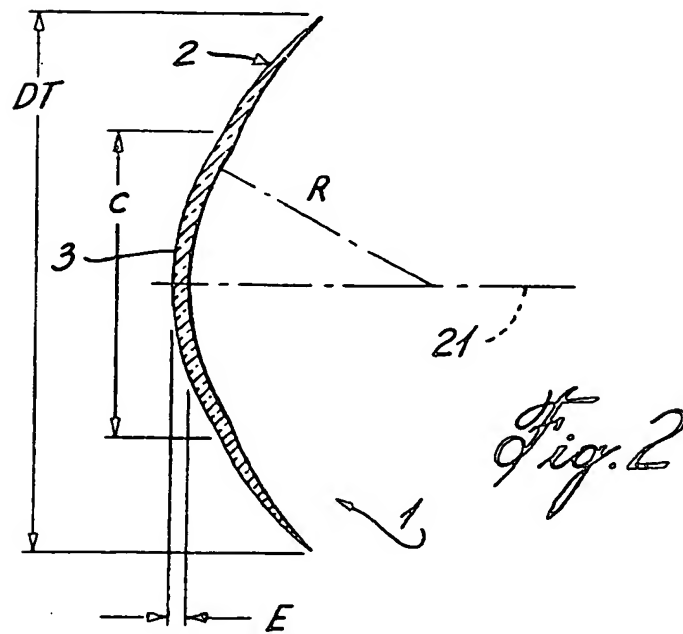
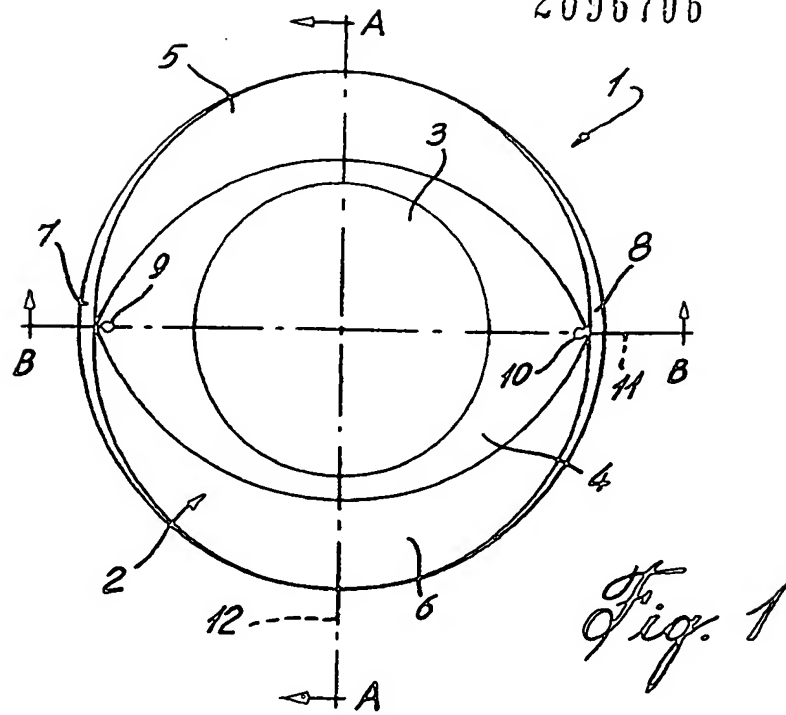
11. A contact lens as recited in claim 8, wherein said anterior surface is symmetrical about a vertical plane of symmetry, and wherein said anterior surface further comprises peripheral spherical zones symmetrical about said vertical plane

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of symmetry, said lens being thinned in the region of said peripheral spherical zones.

12. A contact lens as recited in claim 8, in which said posterior surface comprises said substantially central toric zone, an intermediate spherical zone, and a peripheral zone defining a surface tangential to the surface of the intermediate spherical zone, said intermediate spherical zone being located between said toric zone and said peripheral zone of the posterior surface.

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André L. Dubuc + Martineau Walker

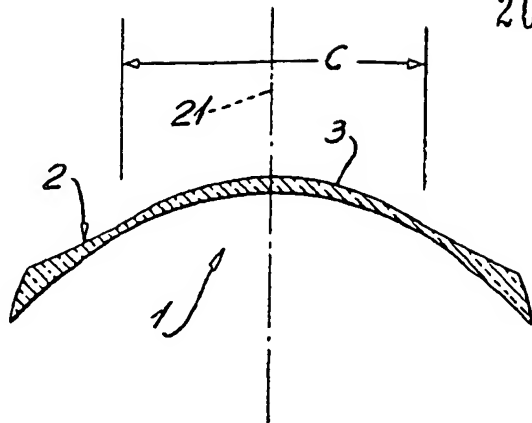


Fig. 3

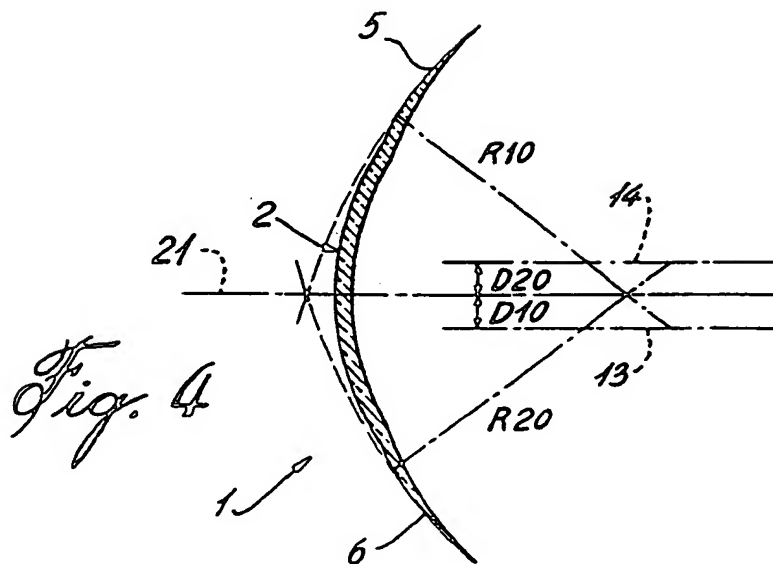


Fig. 4

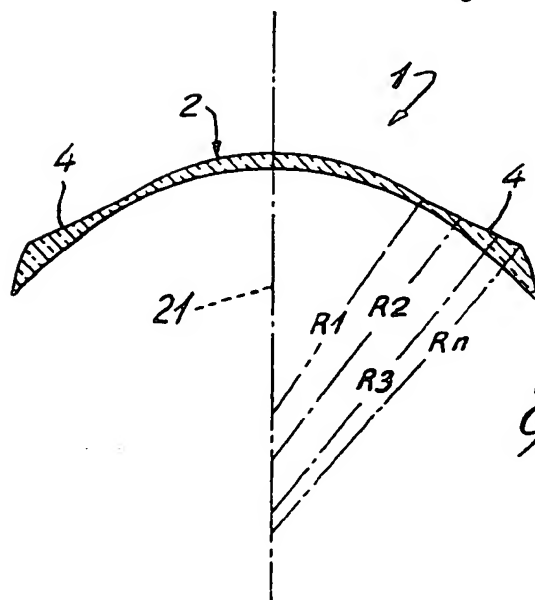


Fig. 5

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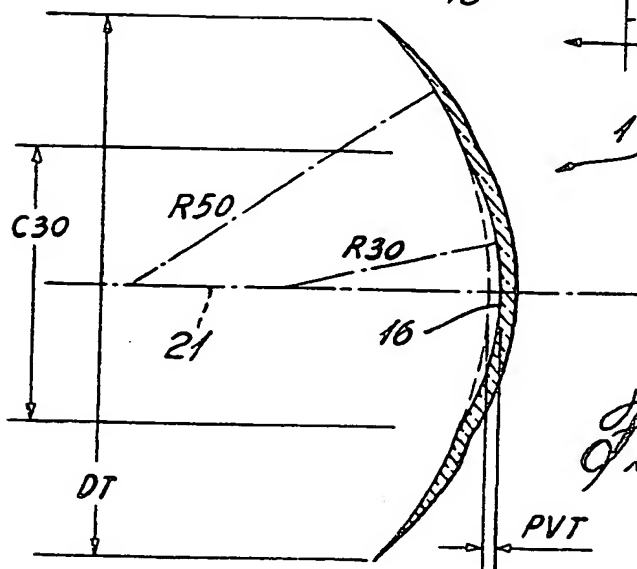
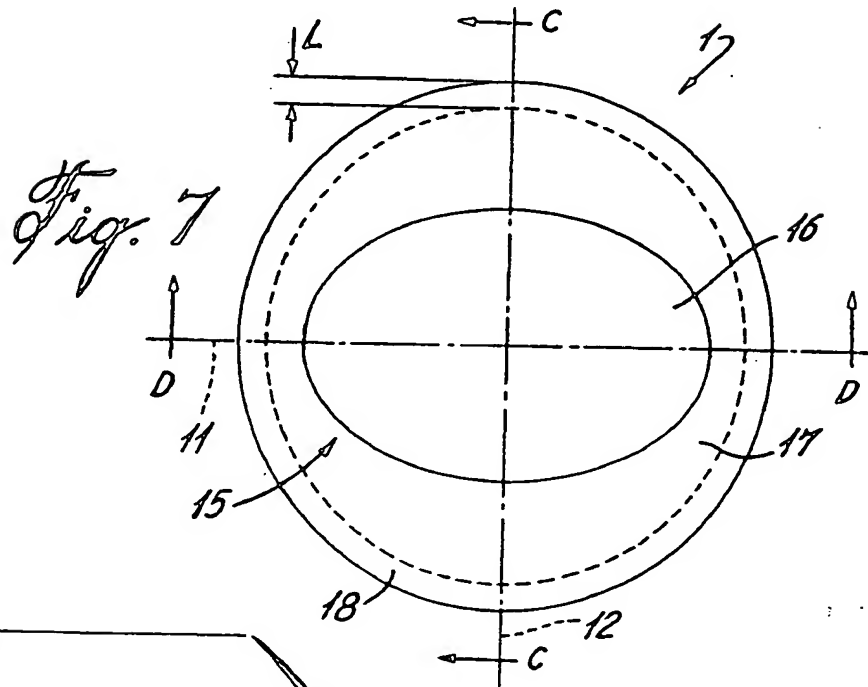
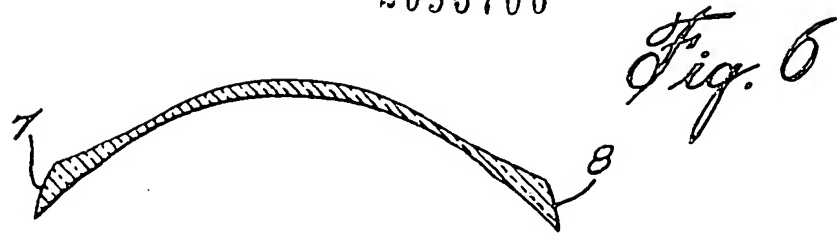


Fig. 8

Gendreau, Gage, Dubuc & Martineau, Woblen

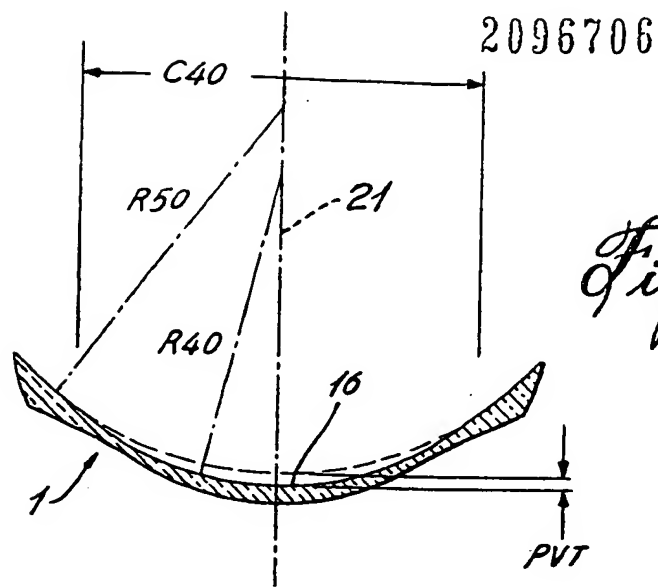


Fig. 9

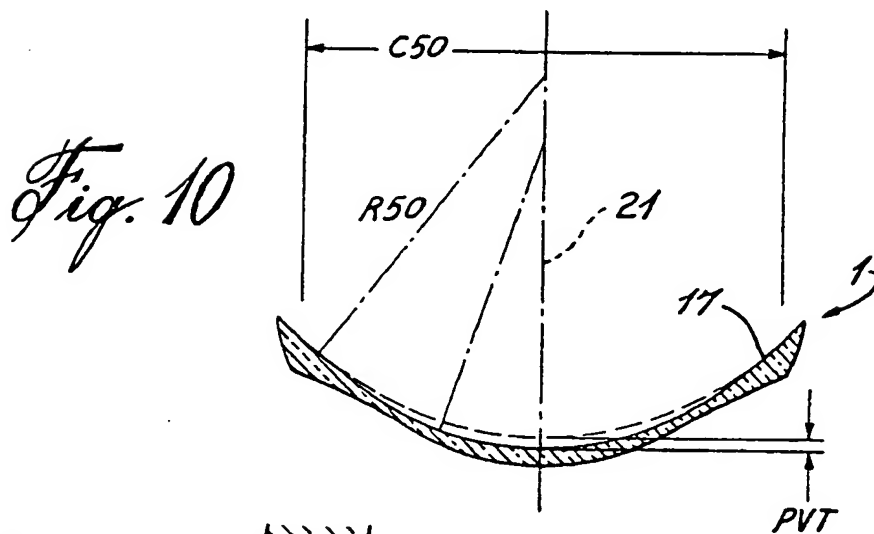


Fig. 10

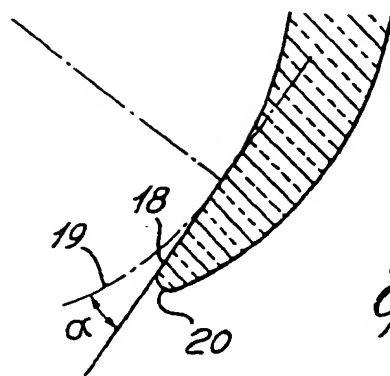


Fig. 11

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